Use of the Scientific Method in the Evaluation of Contaminated Sediment Sites

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May 31, 2001

Common Contaminated Sediment Site Evaluation

- **Characterization data are collected at site**
- **High contaminant concentration and mass ("hot spot") locations are determined**
- **Known sources are quantified**
- **Feasibility study is focused on ways to remove high concentration/mass sediments & eliminate known sources**
- **Hypotheses used in this "common sense" method:**
  - High concentration/mass sediments and ongoing sources are: 1) responsible for unacceptable risks and 2) contaminant source for other areas of the site
  - Addressing high concentration/mass sediments and known sources will reduce risk to acceptable levels

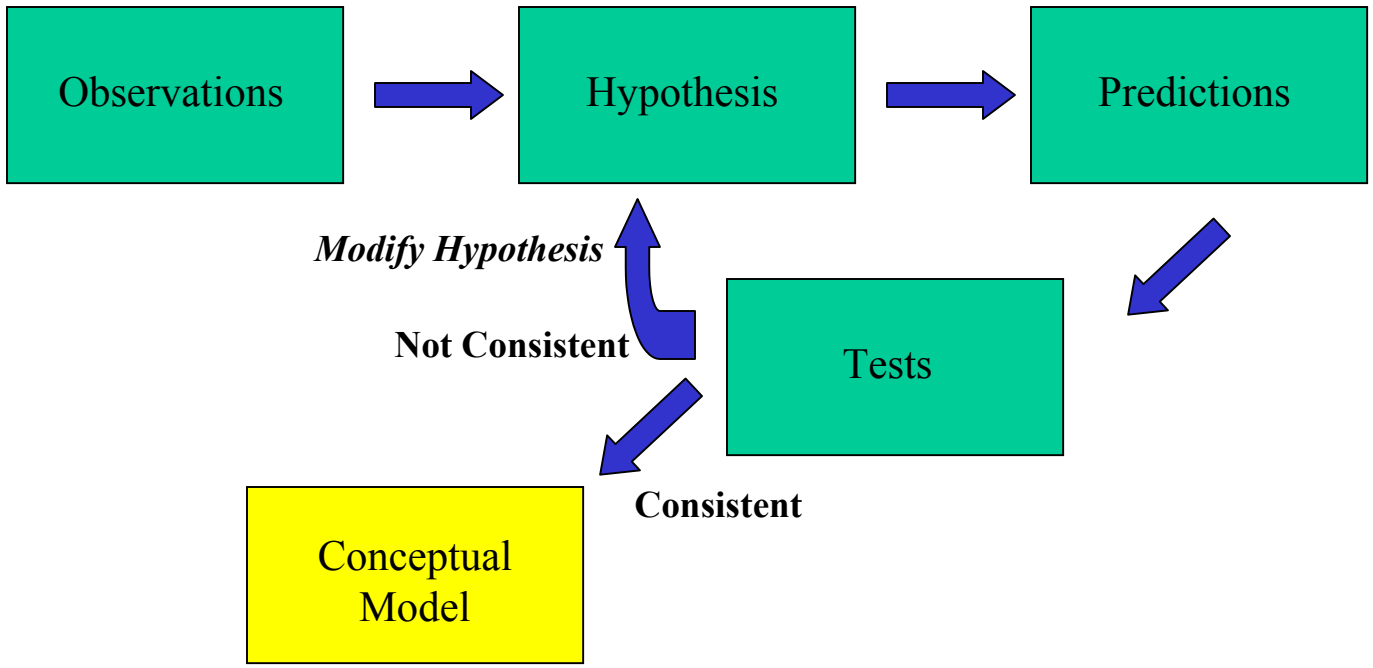
Weaknesses in Typical Site Evaluation Method

- **Usually, no testing of hypotheses**
  - Testing is critical for determining validity of hypotheses
- **Consistency between various hypotheses is not assured**
  - No development of comprehensive conceptual model for site
- **This approach does not follow Scientific Method**

Precedent for Requiring the Scientific Method

- **Supreme Court decision in Daubert v. Merrell Dow Phamaceutical, Inc. (1993) established the standard for admitting expert scientific testimony in a federal trial**
  - "Scientific methodology … is based on generating hypotheses and testing them to see if they can be falsified; indeed, this methodology is what distinguishes science from other fields of human inquiry"

Site Evaluation Using the Scientific Method



Step 1: Use Site Characterization Data to Form Hypotheses

- **Importance of ongoing sources**
- **Distribution of the sediment source**
- **Nature of the sediment source**
  - Bioavailable depth (i.e., depth contributing contaminant to biota & water)
  - Mechanisms for contaminant flux (diffusion; ground water; resuspension)
- **Pathways & extent of exposure to contaminant**
  - e.g., bioaccumulation pathways
- **Stability of the sediments (risk of remobilization of buried contaminant)**
- **Rate and mechanisms of natural recovery**

Characteristics of Valid Hypotheses

- **Consistent with scientific understanding of the relevant issues**
- **Can be tested**

Step 2: Test Hypotheses

- **Develop tests of the hypotheses**
  - if this hypothesis is correct, than the following should be true
- **Conduct tests using *all* existing data**
- **Obtain new data to test hypotheses when existing data are insufficient to discriminate between alternative hypotheses**

Step 3: Develop Comprehensive Conceptual Model

- **Addresses all the important issues**
  - ongoing sources; distribution and nature of sediment source; sediment stability; exposure pathways; natural recovery
- **Contains no inherent contradictions**
- **Explains *all* the observations at the site**

Example of Hypothesis Testing on the Hudson River

- **Observation: PCB levels in the surface layer of the "hot spot" sediments declined by 90% between 1977 and 1998**
- **Why?**
- **Hypotheses:**
  - reductions in PCB loading to the river have resulted in reductions in the PCB concentration on particles that are accumulating in the hot spots. These lower concentration particles are burying the higher concentration sediments.
  - PCB containing sediments have been remobilized and transported from the "hot spots" to other locations
  - PCBs have been biodegraded

Evaluation of Possible Hypotheses

- **Estimate change in PCB mass in the hot spots**
  - no statistically-significant change has occurred
- **Estimate quantity of PCBs that has been transported downstream**
  - a few percent of the inventory has moved downstream
- **Test for evidence of degradation**
  - degradation limited to subset of congeners and only at higher concentrations
- **Model the burial process and the fate of the sediment PCBs**
  - inventory is sequestered due to burial and cohesive sediment armoring during high-flow events

Quantitative Mass Balance Models Play a Key Role in Hypothesis Testing

- **Models can "limit arbitrary action," "achieve consistency," and "'unpack' crude risk-assessment numbers and simple qualitative conclusions through comparisons that illuminate the nature of relevant uncertainties."**
  - Stephen Breyer, Breaking the Vicious Circle: Toward Effective Risk Regulation, 1993.

Summary

- Scientific Method should be followed when performing evaluation of a contaminated sediment site
- Testing validity of hypotheses and conceptual model is a critical step in the site evaluation process
- Computer models can be a useful tool for hypothesis testing